Multi-Year Habitat Monitoring at Johnsons Mill Dam Removal – 2024 Annual Report

STONE ENVIRONMENTAL

PROJECT NO.

19-093

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Cover Photo: Bogue Branch looking downstream at former dam location.

Contents

List of Figures

List of Tables

1. Introduction

The Johnsons Mill Dam removal was completed in August 2021. Prior to full removal, the dam was partially breached during a 100-year storm event that occurred on October 31, 2019. The dam was constructed of stone and concrete, and was located along the Bogue Branch in Bakersfield, Vermont. The Bogue Branch is a tributary to the Tyler Branch which flows into the Missisquoi River. The watershed area draining to the Johnsons Mill Dam location (44.83141, -72.75578) is 8.63 mi^2 (StreamStats, 2019). A majority of the watershed is forested, with only 2% considered developed land (StreamStats, 2019).

Post-removal monitoring is being completed along the Bogue Branch to improve our understanding of aquatic organism habitat following dam removal and address knowledge gaps related to a removal design that had a minimal amount of sediment removed from the upstream impoundment prior to dam removal. Monitoring takes place annually over the course of four years post-removal and includes streambed analysis, topographic and bathymetric surveying, woody debris evaluation, and plant survival and coverage assessment; algal and macroinvertebrate analysis were not completed in 2024. Data collected will allow us to assess changes in stream habitat over time and increase our understanding of post-dam removal stream dynamics. This report summarizes the monitoring methods and results for 2024, the third year of monitoring.

2. Monitoring Data Collection & Analysis Methods

The monitoring reach extends from Witchcat Road near the intersection with Joyal Road to just north of 1505 Witchcat Road, as shown in Figure 4. The monitoring reach is subdivided into three sub-reaches numbered from upstream to downstream. Reach 2 correlates to the limits of disturbance during dam removal (Figure 1, Figure 4). Year Three monitoring for streambed sediment, wood recruitment, and vegetation was performed on September 20, 2024, using a combination of ESRI Field Maps, Survey 123, and a Trimble R2 GPS unit. Monitoring locations are shown in Figure 1. Drone Imagery was collected by Stone Environmental on March 25, July 29, and October 25, 2024, and by Whiteout Solutions on June 5, 2024.

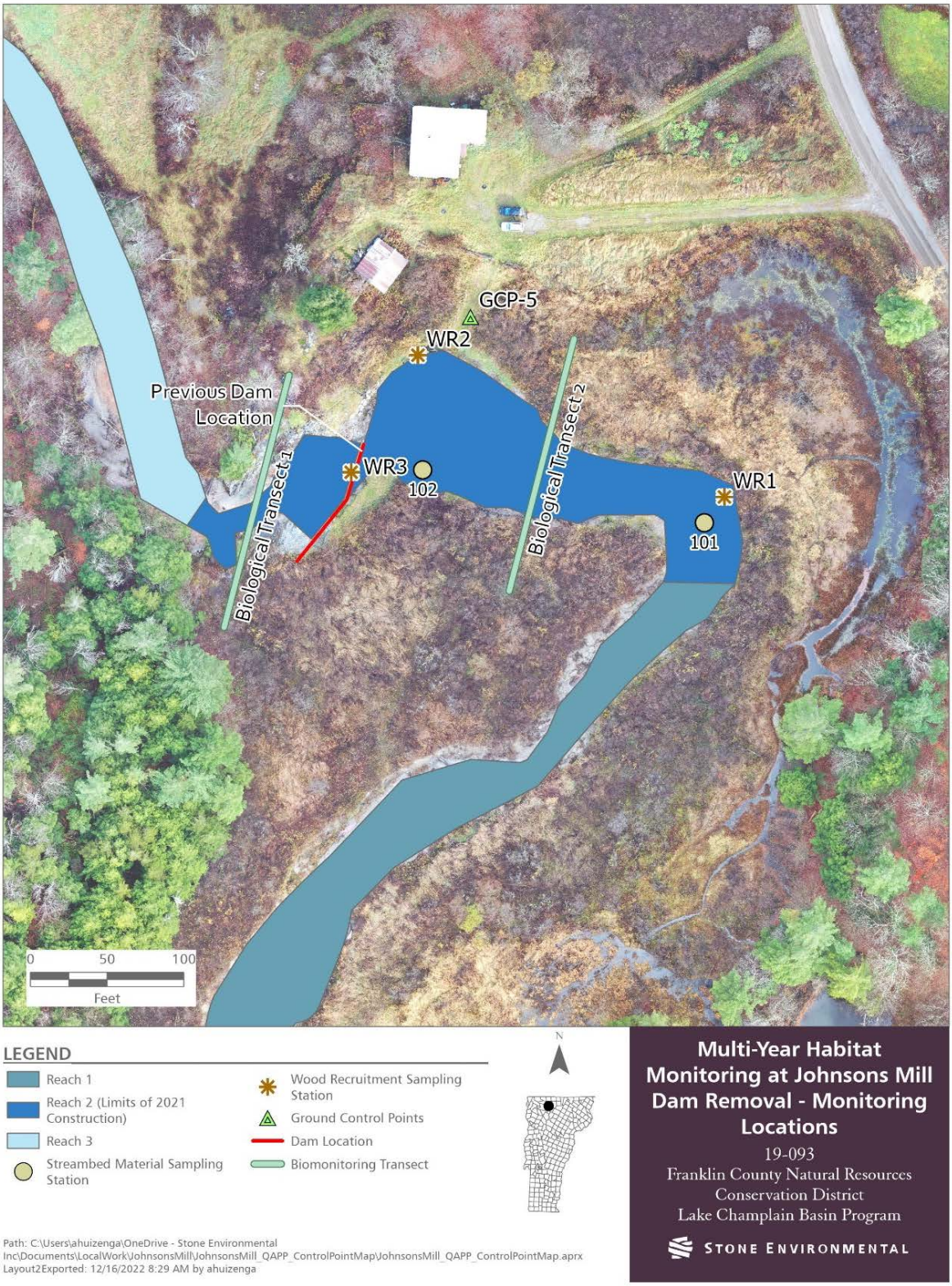

Figure 1. Wood recruitment, sediment sampling, and biological sampling locations established during Year One (2022) monitoring and revisited during subsequent monitoring events.

2.1. Streambed Material Analysis

Stone staff collected streambed material data at Sites 101 and 102 on September 20, 2024, representing different habitat types within Reach 2 (See Figure 1 for locations). The same locations were also assessed during Year One (2022) and Year Two (2023) monitoring. At each location, Stone staff completed pebble counts using the Wolman pebble count method to determine grain size distributions. After pebble counts were completed, visual and tactile assessment methods were used to determine relative percentages of material beneath the surficial armor layer at one location toward the center of the channel at each streambed monitoring site. Each habitat feature, or monitoring location, was inspected for roughness boulders in accordance with the project Quality Assurance Project Plan (QAPP). Dimensions and angularity were recorded for each identified roughness boulder. Data were entered into ESRI Field Maps and Survey123 field forms and processed in MS Excel to determine grain size distributions and approximate percentage of materials. Photos were taken of each station.

2.2. Evaluation of Wood Recruitment

As explained in the Year One (2022) Monitoring Report, initial monitoring plans for wood recruitment in Reach 2 consisted of assessing recruitment at the rootwad installations completed during construction. These installations were made along two meander bends within Reach 2 and are identified as WR1 (upstream) and WR2 (downstream) in Figure 1. Channel migration and incising that occurred following dam removal resulted in the disconnection of the downstream rootwad installation (WR2) from the main channel and suspension of the upstream rootwad installation (WR1) above the water surface. As a result, a third monitoring location (WR3) was identified while in the field on November 2, 2022. WR3 is located directly upstream of the prior dam location and consists of a timber cribbing that was uncovered following dam removal and has begun to recruit wood. These stations were revisited for monitoring in 2024.

The following data were collected for each wood recruitment monitoring station:

- Embeddedness in bank (distance from tag to bank) (only applicable for installed rootwads at WR1 and WR2)
- Tag ID
- General condition
- Count, length, diameter, and tag ID of recruited wood
- Photos

Natural woody debris and timber logs greater than 3" in diameter within bankfull width were also tagged, measured, and recorded in ESRI Field Maps and Survey123. Blue metal tags were affixed near the collar of the rootwads or one end of a timber log using nails (Figure 2 and Figure 3). Qualitative notes regarding the potential source of woody debris were recorded (i.e., natural recruitment vs timber log). The total count and distribution of wood length and diameters were quantified in MS Excel. Maps were created using ArcPro 3.3.2 to depict the location and relative characteristics of rootwads and tagged wood in the channel within Reach 2.

Figure 2. Stone staff tagging and collecting GPS locations of wood at monitoring station WR3.

Figure 3. Image of an installed rootwad at WR2 with the blue metal tag highlighted with a blue circle.

2.3. Evaluation of Plant Survival and Coverage

Plant communities were initially assessed on November 2, 2022, and reassessed during the third year of monitoring on September 20, 2024. Stone staff walked from the prior dam location upstream to the beginning of Reach 1 to identify plant communities, tree stands, and individual trees within 30 feet of the channel along

river left and river right. Plant and tree stands were delineated using the GPS unit. The following data were recorded as appropriate for each stand and individual tree:

- Leaf condition
- Stem condition
- Evidence of pests and/or disease
- Species composition
- GPS coordinates
- Photos

2.4. Aerial Imagery

Stone staff collected aerial imagery of the AOI on three occasions in 2024. This imagery provides data on changes that may occur between the annual geospatial data collection completed by Whiteout Solutions and described in Section 2.5. Stone staff collected aerial imagery using a DJI Mavic 2 Pro drone flown at an elevation of approximately 350 ft. Imagery was collected on March 25, July 29, and October 25, 2024. Images were processed and orthorectified using DroneDeploy. The resulting orthomosaic and digital terrain model (DTM) will be shared with FCNRCD and are presented in maps within this report.

2.5. Topographic, Bathymetric, and Vegetation Indices Surveys

2.5.1. Data Collection

Beginning in 2023 (second monitoring year), Whiteout Solutions collected geospatial data using a fleet of unmanned aerial vehicles (UAVs). The geospatial data collected included topographic, bathymetric, and vegetation indices for the 84-acre area of interest (AOI) shown in Figure 4. Vegetation data (including NDVI imagery), topographic, and bathymetric data were collected using a drone on June 5, 2024.

Prior to collecting geospatial data with UAVs, Stone staff established ground control points (GCP) GCP-1, GCP-2, GCP-3, GCP-5, and GCP-6 as seen in Figure 4. Whiteout Solutions reestablished these GCPs in 2024 to establish the vertical and horizontal datum. Ground control points are 24" lengths of 3/8" rebar driven into the ground with an orange cap flush at existing ground elevation. Grade stakes with survey flagging were also driven adjacent to the ground control points to aid in locating the control in the future.

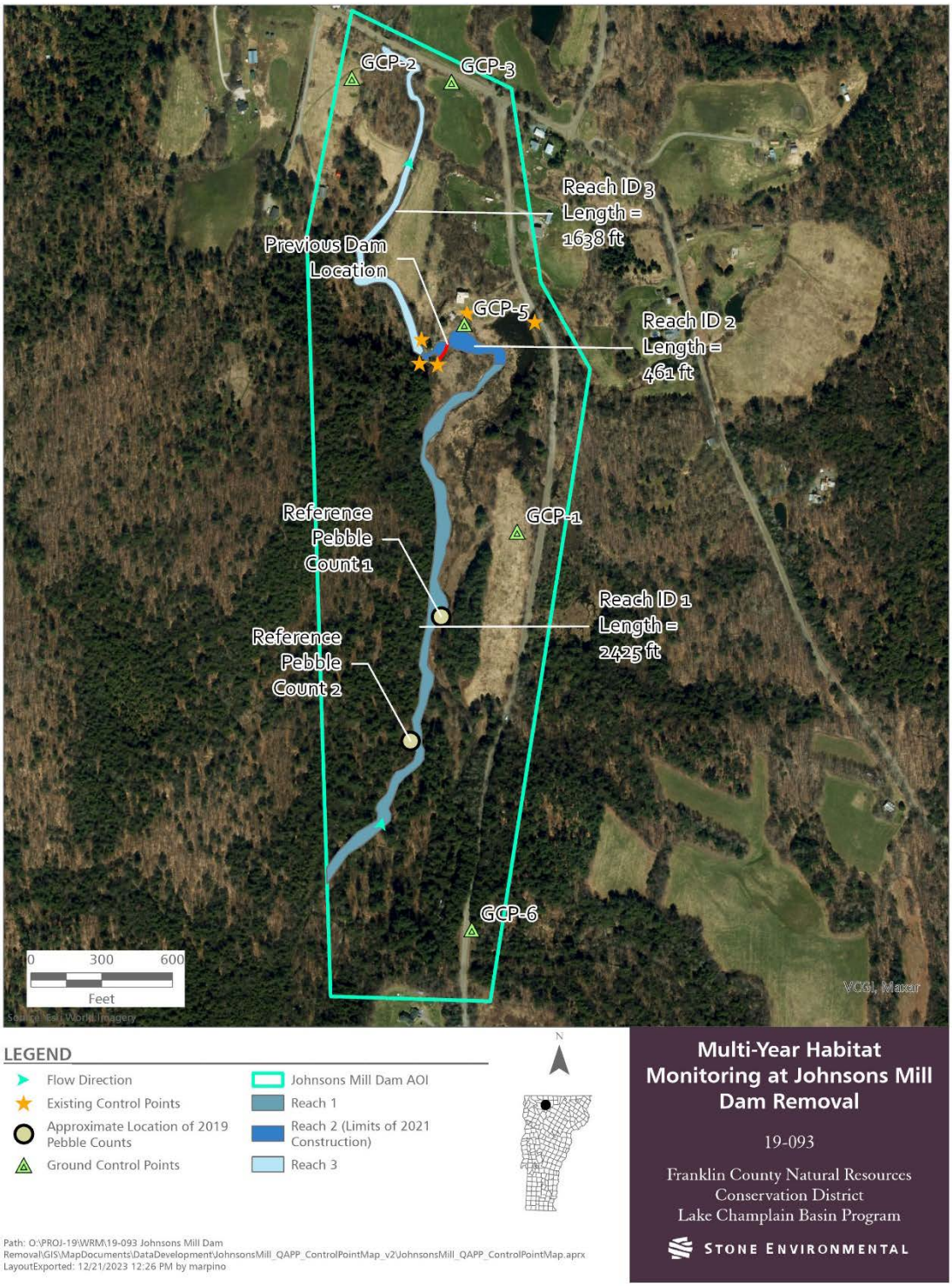

Figure 4. AOI and monitoring reaches identified for multi-year monitoring.

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2.5.2. Topographic and Bathymetric Data Analysis

The availability of topographic and bathymetric data from multiple points in time pre- and post-dam removal makes it possible to assess changes over time at the Johnsons Mill site. However, the available data collected prior to 2023 were not all collected in the same datum, for the same extent, or using the same methods. The available datasets are summarized in Table 1.

Table 1. Summary of Available Datasets

Surface No.	Collection Details	Type	Description
0	December 2019, Stone Environmental	Total Station Survey	Pre-dam breach existing conditions surface
1	January 2020, Stone Environmental	Total Station Survey	Post-dam breach existing conditions surface
2	August 2021, Stone Environmental	Total Station Survey	As-built survey data used to create a DEM
3	April 2022, University of Vermont	Topographic Lidar Only	Post-dam removal lidar for entire 84-acre AOI
4	June 2023, Whiteout Solutions	Topographic and Bathymetric Lidar	Monitoring geospatial data collection using UAVs for the entire 84-acre AOI
5	June 2024, Whiteout Solutions	Topographic and Bathymetric Lidar	Monitoring geospatial data collection using UAVs for the entire 84-acre AOI

Beginning in 2023, the datasets were reviewed and processed to allow initial comparisons of the DEMs. Each dataset was imported into ArcPro 3.3.2 and transformed to match the projection and datum of the Whiteout Solution topographic and bathymetric data. Once the DEMs were in the same projection and datum, longitudinal profiles and channel extents were traced to assess vertical and lateral channel adjustments. Additionally, the DEMs created from the pre-breach, post-breach, and post-dam removal survey data are being compared using the cut fill tool in ArcPro 3.3.2 to estimate the volume of sediment released during the dam breach, the volume removed during construction, and sediment transport during the monitoring years. These methods and results will be described in the final monitoring report. One limitation of this comparison is the represented extent as the survey data does not extend upstream of the former impoundment. Additional data comparison challenges have arisen due to the differing resolutions of the datasets.

2.6. Algal Analysis

Algal data collection was not completed in 2024.

2.7. Macroinvertebrate Analysis

Macroinvertebrate surveys were not completed in 2024.

3. Monitoring Results

3.1. Additional Concrete Removal

On-going monitoring provides the opportunity to adaptively manage the project site. In Year 2, ongoing channel erosion and adjustment revealed remaining concrete from the original dam that had been missed during project construction. The remaining concrete had the potential to inhibit aquatic organism passage. The project excavation contractor was able to remove the remaining concrete in the summer of 2024. The remaining concrete is shown in Figure 5 and removal of the concrete is shown in Figure 6.

Figure 5. Looking upstream at remaining concrete uncovered during Year 2 monitoring.

Figure 6. Excavator removing remaining portion of the dam in August 2024. Photo source: FCNRCD

3.2. Streambed Material Analysis

Figure 7 presents grain size distribution plots developed using the pebble count data collected at Site 101 and Site 102. When established, Site 101 was in a pool and Site 102 was a riffle. In 2023, these were still the dominant stream habitat types at these locations, but by 2024 the channel had adjusted so that Site 101 is now primarily a riffle and Site 102 a pool. Figure 7 presents the grain size distribution for the two sampling locations over time. Reference reach pebble counts were completed in a portion of Reach 1 on October 21, 2019, prior to the dam removal and are included for comparison. Figure 4 includes the approximate locations of the reference reach pebble counts. In 2022 and 2023, the dominant particle size in the pool (Site 101) was sand (<2 mm) and silt (<0.0625 mm), and in 2024 the dominant particle size in the pool (Site 102) was still sand (<2mm) but there was less silt content than the previous years.

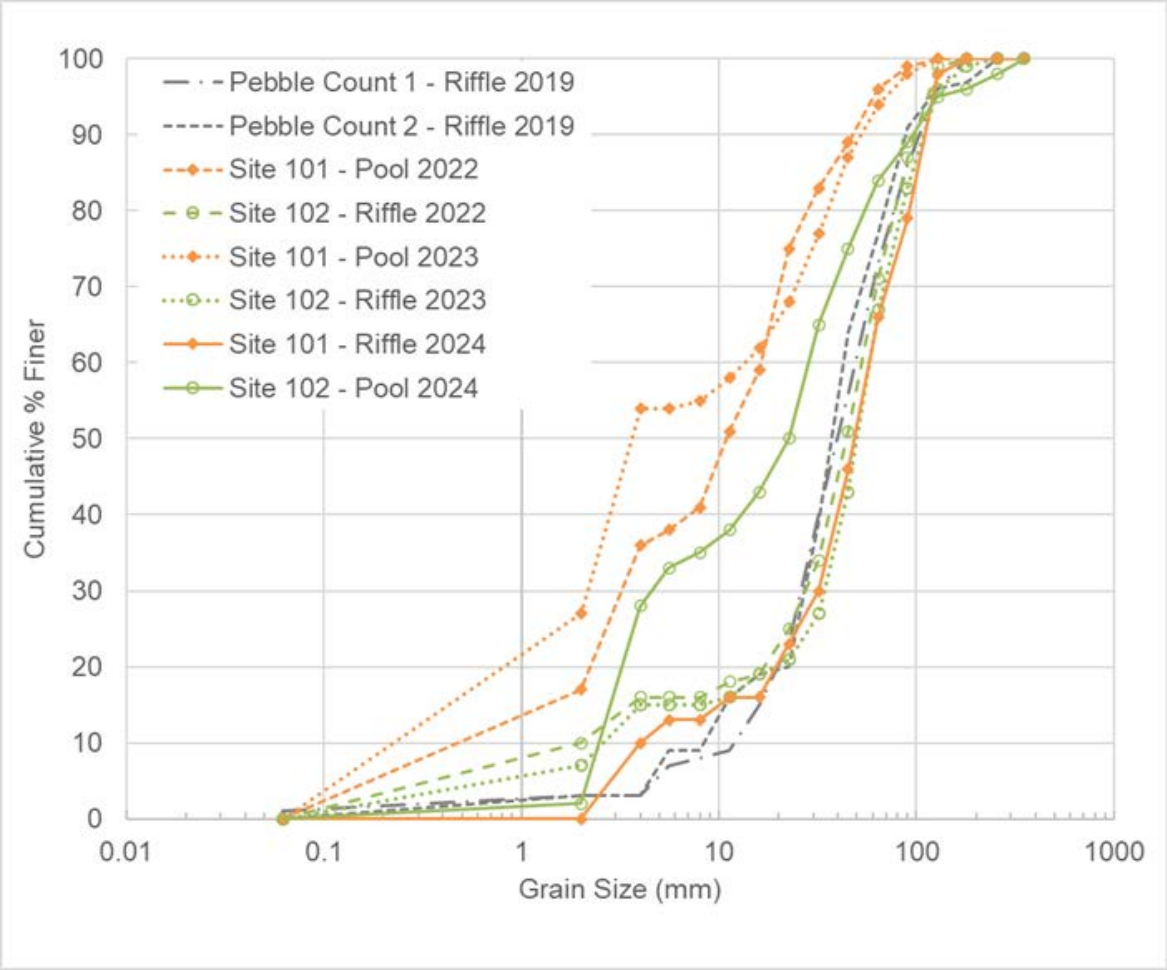

Figure 7. Cumulative grain size distributions pre- and post-removal. Note, pre-removal (2019) pebble counts were completed in the upstream reference reach (see Figure 4 for approximate location) and not at the same locations as the sediment sampling stations established for multi-year monitoring.

No roughness boulders were identified at the sediment sampling locations in 2024. This is consistent with a decreasing trend of roughness features observed throughout the monitoring period and may also reflect the prevalence of high flow events in 2023 and 2024 causing reworking of the monitoring reach. Roughness boulder characteristics observed at Site 102 in Year One and Year Two are summarized in Table 2.

Table 2. Roughness boulder characteristics observed within the riffle at streambed monitoring Site 102.

Year	Count	Length (in)	Width (in)	Height (in)	Embeddedness (%)	Angularity
2022	1	520	360	300	50	Sub-rounded
	2	350	170	140	0	Sub-angular
	3	280	130	100	5	Sub-rounded
	4	300	155	120	25	Sub-angular

2023	1	470	310	170	50	Sub-angular

Results of the visual and tactile assessment of sediment beneath the surficial layer are summarized in Table 3. Photos are provided in Figure 8. Gravel was the dominant sediment type at both locations, followed by sand at the pool and particle sizes smaller than sand below the riffle surficial armor layer.

Table 3. Summary of visual and tactile assessment results for sediment below the surficial layer.

Year	Location	Gravel (%)	Sand (%)	< Sand (%)
2022	Pool (Site 101)	75	20	5
	Riffle (Site 102)	70	10	20
2023	Pool (Site 101)	33	33	33
	Riffle (Site 102)	50	25	25
2024	Pool (Site 102)	15	80	5
	Riffle (Site 101)	90	5	5

Figure 8. Photographs of the sediment below the surficial layer at Site 101 (left photo) and Site 102 (right photo) in Monitoring Year Three.

3.3. Evaluation of Wood Recruitment

Evaluation of wood recruitment included assessing installed rootwads and naturally recruited woody debris within the channel. Figure 9 depicts the spatial distribution and migration of tagged woody debris and rootwads within Reach 2.

In 2023, Stone staff observed that all the rootwads from WR1 had been dislodged from the bank and only three of the five rootwads were found downstream within the monitoring reach, with the remaining two assumed to have been carried downstream beyond the monitoring reach. There had been little to no change at WR2 in 2023, likely due to the disconnection of these rootwads from the main channel.

In 2024, no change was observed at the WR1 and WR2 locations due to the migration of the channel and bank failure disconnecting or dislodging the installed rootwads. The two rootwads originally at WR1 are at the same location on the gravel bar where they were observed in 2023, and the rootwads at WR2 remain

disconnected from the channel. The woody debris tagged as WR3 (ID 108) to add an additional potential wood recruitment monitoring location migrated 13 feet downstream by the Year 3 monitoring date WR3 has not recruited any large woody debris. Table 4 summarizes counts of woody debris within the monitoring reach for each year, wood not recovered in subsequent years, and newly tagged wood. Though 14 new wood pieces were tagged in 2024, it is possible that some of the wood tagged in 2024 had been tagged in previous years and moved enough so that the original tag was not visible during the monitoring event. In two instances the tags could not be located but Stone staff used comparison to the previous year's photo, notes, and location to infer that the wood was likely the same piece from last year.

Table 4. Summary of woody debris within the monitoring reach by year.

Year	Total Count of Woody Debris Present[1]	Count of Tagged Wood Not Recovered	Count of Newly Tagged Wood
2022	15	NA	NA
2023	13	7	3
2024	21	7	14

[1]*Does not include installed rootwads*

Possible considerations for the Year Four (2025) monitoring effort include walking the downstream reach (Reach 3) to identify previously tagged woody debris that has moved downstream, and evaluating whether to continue monitoring wood recruitment at the rootwad installation location since the installations are not functioning as designed.

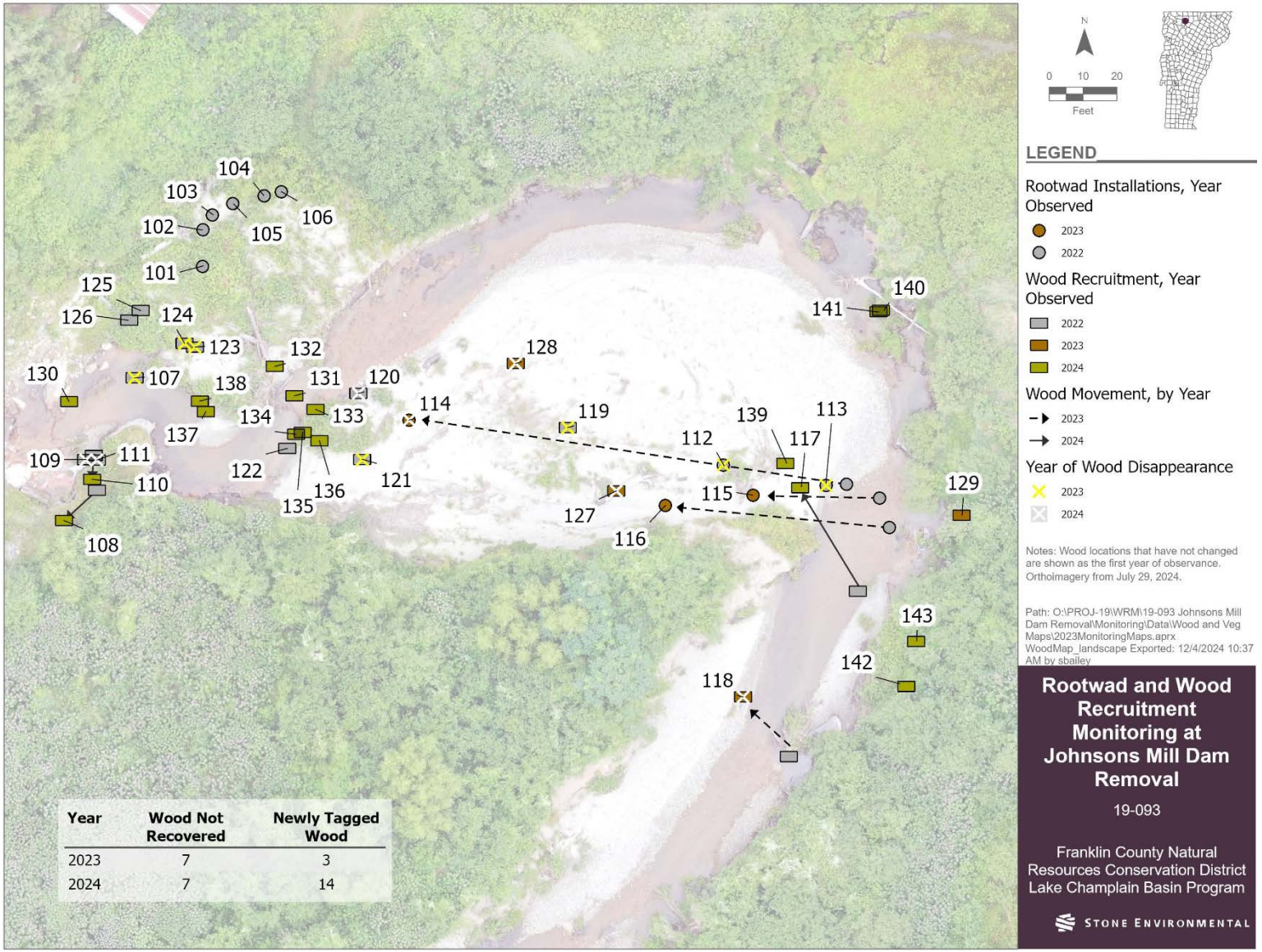

Figure 9. Change over time of the spatial distribution of rootwads and channel-recruited woody debris.

As in 2023, much of the tagged woody debris pieces were timber logs that had previously been buried under the dam impoundment and may have been part of timber cribbing or other structures associated with the dam. These timber logs became exposed following dam removal and the subsequent channel adjustment. Table 5 presents the migration distances of tagged woody debris observed multiple years. Figure 10 through Figure 12 summarize the dimensions and general locations of the woody debris greater than 3 inches in diameter and compare the monitoring years. The total volume of the recruited wood equaled approximately 400 cubic feet. Include two rootwads that are now located in the channel. Woody debris is primarily being recruited along the river left bank (looking downstream) or on the point bar located at the meander bend upstream of the former dam location.

Table 5. Migration distances of woody debris from 2022 to 2024.

Wood Tag ID	Distance Downstream in 2023 (ft)	Distance Downstream in 2024 (ft)
107	Beyond monitoring reach	-
108	0	13
110	0	7
114	127	Beyond monitoring reach
115	33	33
116	63	63
117	0	35
118	Half buried in left bank	Beyond monitoring reach
119	Beyond monitoring reach	-
121	Beyond monitoring reach	-
123/124	Possibly buried	-

Figure 10. Summary of wood length within the monitoring reach of the Bogue Branch.

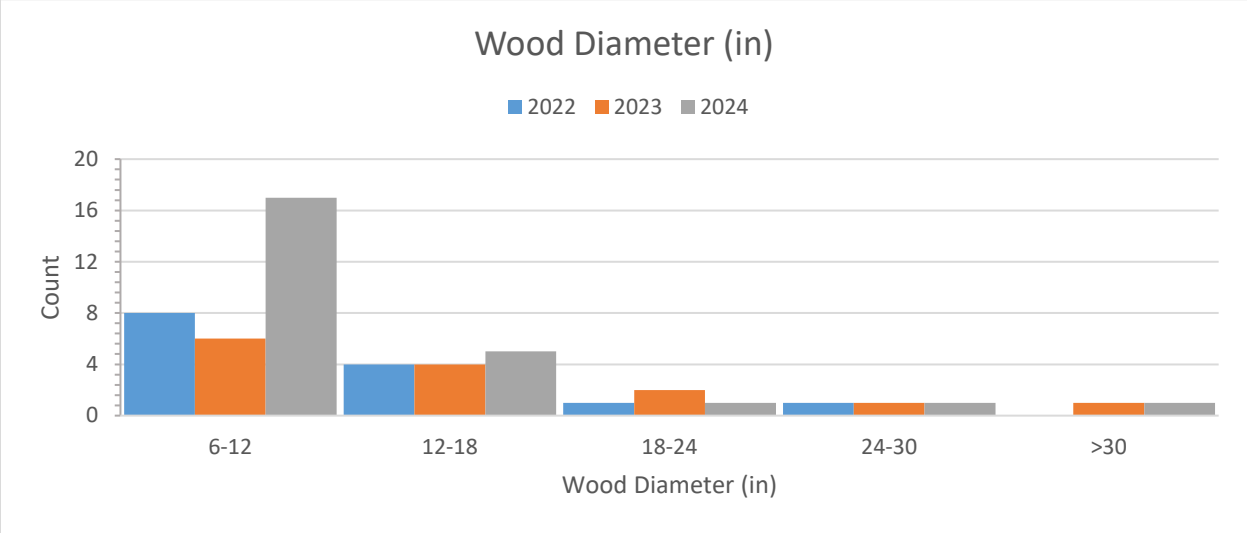

Figure 11. Summary of wood diameter within the monitoring reach of the Bogue Branch.

Figure 12. Summary of wood location within the monitoring reach of the Bogue Branch.

3.4. Evaluation of Plant Survival and Coverage

Plant survival and coverage were assessed to the best of Stone's ability using the initial 2022 assessment as a baseline. Each vegetation stand and mature tree identified was revisited and assessed for plant health. Figure 14 summarizes the 2024 assessment, showing the plant communities and general boundaries between assessed stands of similar vegetation. Stands are distinguished by changes in dominant vegetation type and generally extend to the monitoring extent of 30 feet from the top of bank. The main stands identified were "Planted Willow" (willows planted as part of the stream restoration project), "Natural Willow," "Mature Tree," and "Goldenrod/Grass." Mature trees were marked as individual stands so that their health can be monitored independently of the surrounding stand. Health was assessed using four assessment criteria: leaf health, stem health, evidence of die-off, and evidence of pests. Then a general score of "Good", "Fair", and "Poor" was given to a stand based on those criteria.

The main factor affecting vegetation health is erosion of the stream banks. Stands 3, 8, 18, 19, 20, and 21 have all lost significant area due to erosion. Besides this factor, the health of the vegetation communities in the monitoring reach remains good and no significant draining of the wetland on river right has yet been observed. No significant die-back of the willow and alder stands has been noted. The small alder tree in Stand 21 (S21) that was noted in 2022 has now died due to the pressure of vines such as virgin's bower and bindweed (Figure 13). These vines are prevalent on the river left floodplain area. Stand 9 (S9), a mature American Elm, continues to show signs of stress with dead leaves and some dead branches, which likely indicates it has Dutch Elm Disease.

The planted willows in S1 looked healthy and volunteer native willows have spread in this area. Some disturbance due the removal of remaining dam concrete in August 2024 was observed. Almost all the planted willows in S3 have been removed by erosion but some small alders have begun to establish. No beaver activity was observed during the 2024 monitoring event. Preliminary comparisons were made between the plant stands surveyed in the field and the Normalized Difference Vegetative Index (NDVI) data collected in June 2024 by Whiteout Solutions. In the NDVI dataset, negative values represent water, clouds and infrastructure, positive values near zero are bare ground, and values above zero to one represent vegetated areas with the higher the number indicating denser vegetation. The NDVI data is shown with surveyed polygons in Figure *15*. The stand polygons do not exactly line up with the channel shown in red to yellow tones due to channel

migration that occurred between the NDVI data collection and monitoring. Overall, the green tones representative of denser vegetation are consistent with the dense grasses and shrubs overserved in the overbank area.

Mature willow trees continue to grow on large pieces of slumping bank material on the outside of the meander bend in the monitoring reach. There is a possibility that if these willows survive, their roots may help stabilize the bank material at these locations. These willows will be revisited in Year 4. Figures 16 and 17 show the recent erosion in the monitoring reach and the locations where the photos were taken are shown on Figure 14.

Figure 13. Young alder tree in 2022 (left) and in 2023 (right).

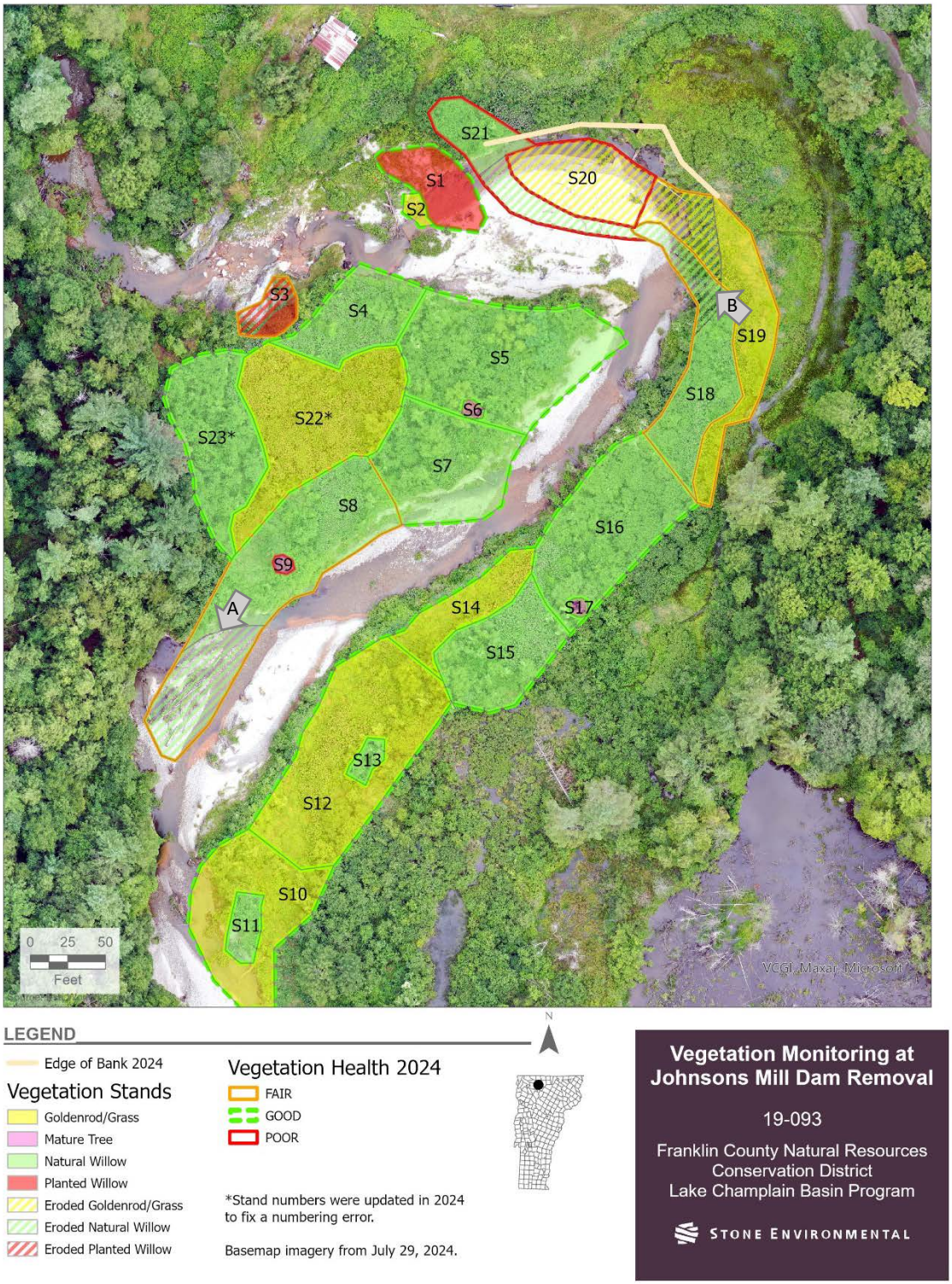

Figure 14. Map of changes to vegetation health in the monitoring reach of the Bogue Branch.

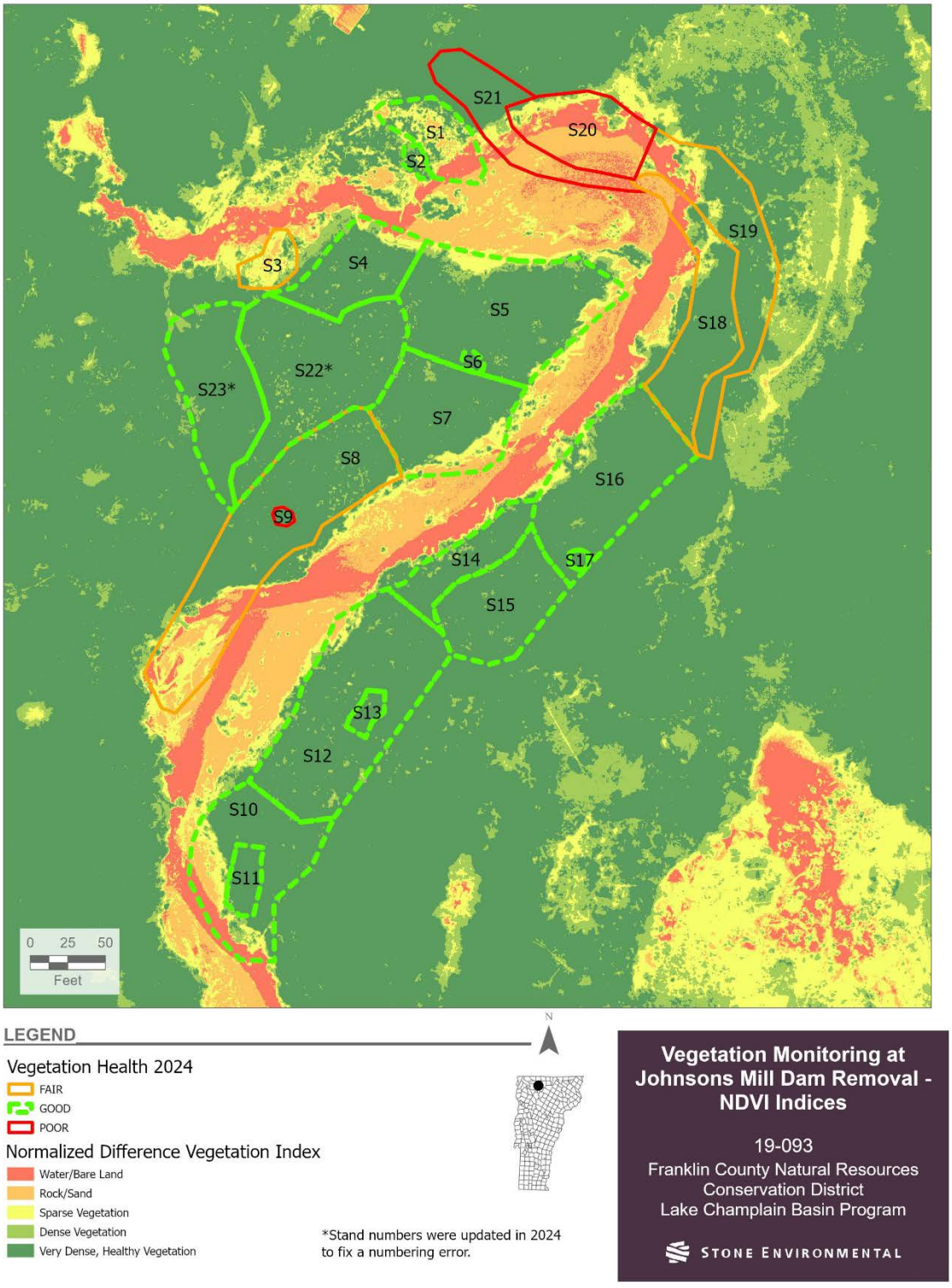

Figure 15. *Vegetation monitoring stands assessed in September 2024 show with NDVI data collected in June 2024. Spots where willows have sloughed into the channel shown as round green areas within the meander bend.*

Figure 16. Photo A: Looking upstream from Stand 8 in 2024.

Figure 17. Photo B: Steep banks along the meander bend in the monitoring reach. Large pieces of bank material with live willows are sloughing into the river.

3.5. Aerial Imagery

Aerial imagery was collected again in 2024 and is compiled in Attachment 1.

3.6. Topographic and Bathymetric Comparisons

A plan to assess topographic and bathymetric change over time using the available pre- and post-removal datasets was developed in 2023. Longitudinal profiles created from the DEMs representing pre-breach (2019) through post-removal (2024) conditions are shown in Figure 18. Due to low flow conditions on the day of collection, the lidar data collected by UVM in 2022 was able to be included in this analysis; however, it should be noted that the UVM UAV system was not equipped with a bathymetric lidar equipment and there may be more uncertainty in the thalweg elevations presented due to noise. These profiles provide information on the vertical adjustment of the channel, an approximately 3 ½ to 4-foot drop is seen immediately upstream of the dam and an approximately 3-foot drop at the upstream extent of the impoundment when comparing the pre-breach (2019) data to the Year Three (2024) elevation data. These changes are consistent with observations made in the field and represent the channel incision observed upstream of the original project limits of disturbance. Based on the DEM comparisons, it is estimated that approximately 1,480 cubic yards of impounded sediment was transported downstream following the dam breach in 2019 and prior to construction. Comparisons were not possible upstream of the upstream extent of the total station survey for these datasets; however, starting in 2023 the longitudinal profile was extended through the entire 84-acre extent with the availability of topobathy data. In Year 3, additional DEM comparisons were begun to help quantify sediment deposition and erosion post-removal. Figure 19 shows preliminary results using volumetric tools in ArcGIS Pro. Next steps in this analysis include further investigation into actual change detected verses noise.

Due to the significant lateral adjustments of the channel within the monitoring reach, we do not propose continuing to update the longitudinal profile comparison in subsequent monitoring years. The stream is increasing in sinuosity which changes the stream's total length within the monitoring reach and complicates the year-over-year comparison of thalweg elevations since thalwegs cannot be compared at the same location.

The pre-breach through 2024 DEMs and aerial imagery were also compared to assess lateral channel migration over time. These comparisons are shown in Figure 20 and depict the lateral migration of the pilot channel to the south immediately upstream of the former dam location. The figure was created by tracing the approximate water surface outline along each bank on the day imagery was collected with comparison to the DEM, where available. In this portion of Reach 2, the pilot channel cut off a meander bend originally included in the design, subsequently disconnecting wood recruitment station WR2. Not captured in this comparison, but visible in the seasonal aerial imagery, is the erosion of the bank where WR1 was installed. It is believed that this bank was likely eroded during the July 2023 flood and has continued to erode through 2024.

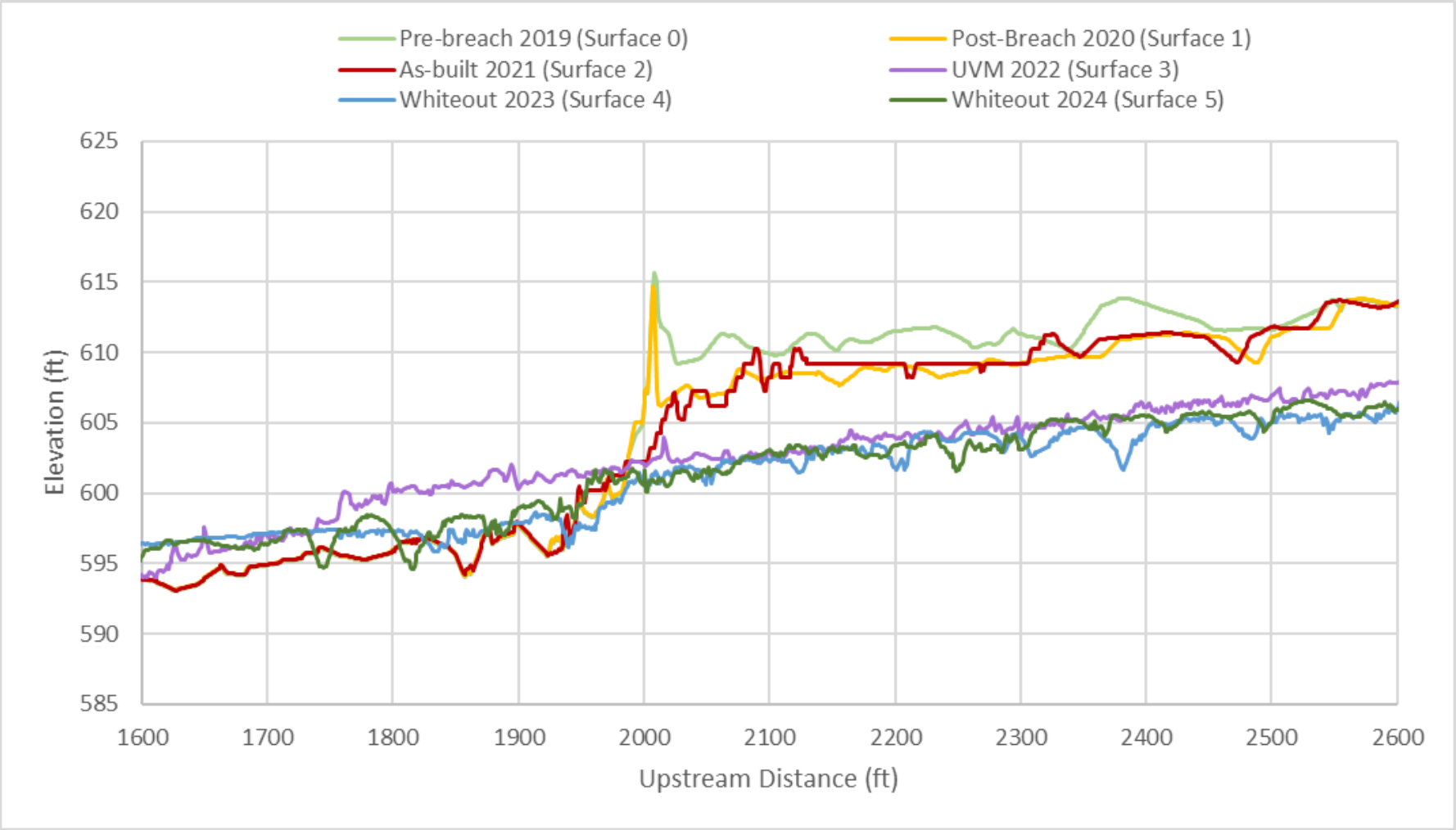

Figure 18. Longitudinal profile comparison of thalweg elevations within the dam removal design extents.

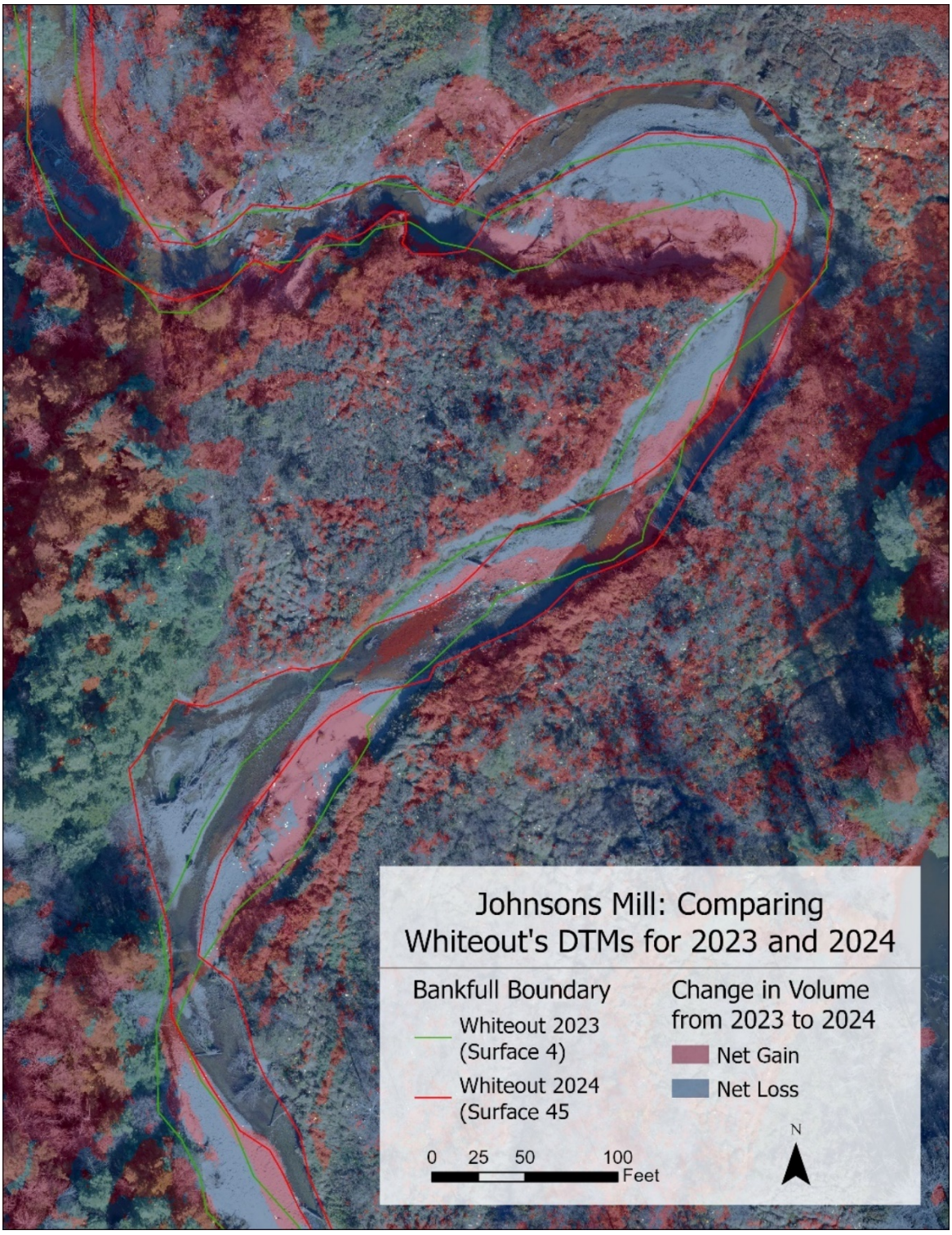

Figure 19. Preliminary identification of zones of sediment gains and losses between 2023 and 2024.

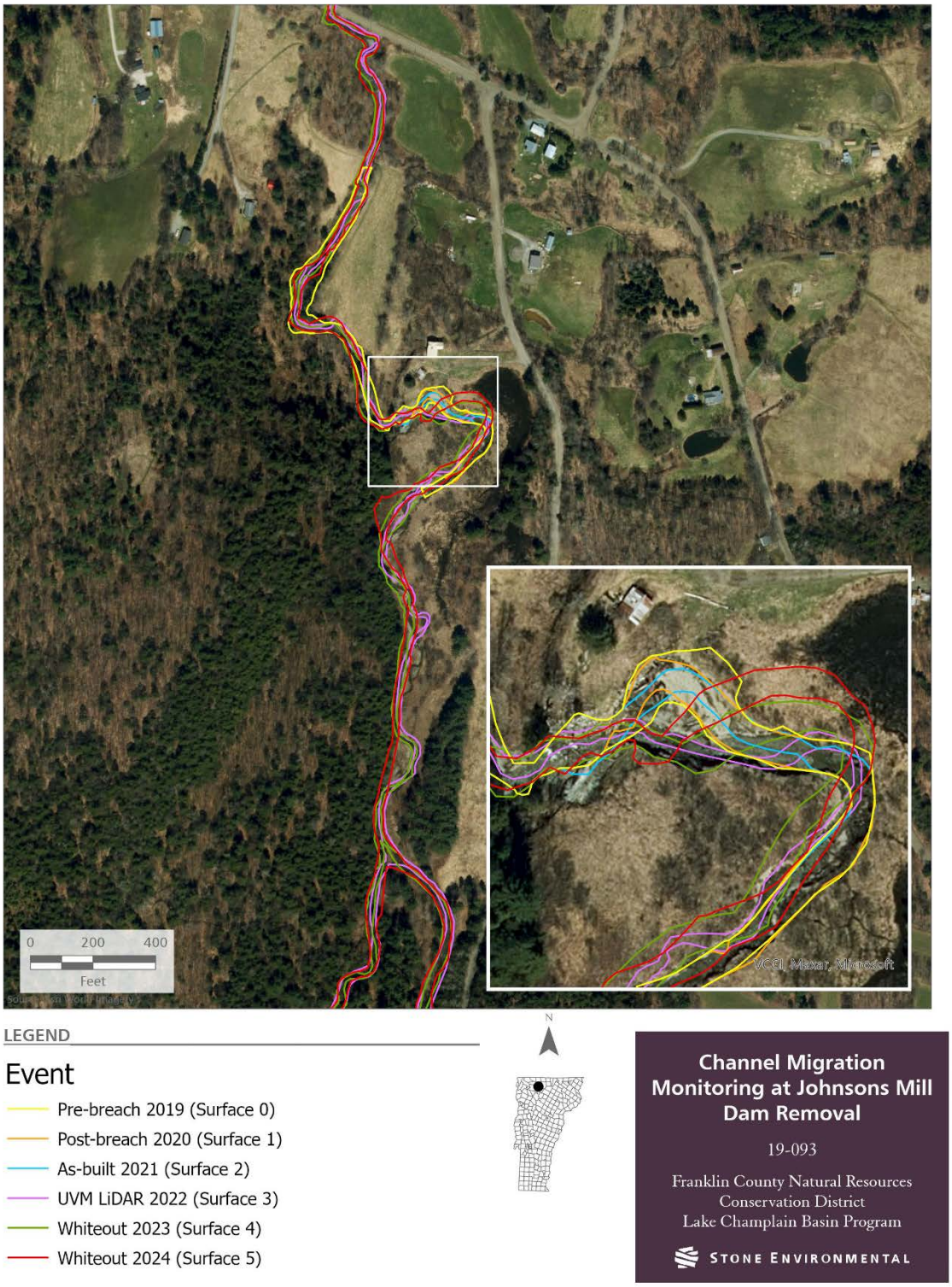

Figure 20. Map depicting lateral channel migration for the approximate water surface outline from pre-breach (2019) through to Monitoring Year Three (2024).

3.7. Algal Analysis

Avacal Biological Consulting was unable to complete data collection in 2024. This was not reported until late December 2024. A new biological consultant will be used in 2025.

3.8. Macroinvertebrate Analysis

Avacal Biological Consulting was unable to complete data collection in 2024. This was not reported until late December 2024. A new biological consultant will be used in 2025.

4. Conclusions

The 2024 monitoring data indicates that the Bogue Branch is continuing to adjust in and beyond the vicinity of the former Johnsons Mill Dam and dam removal project extents. These changes are attributable to the dam removal and pilot channel responses to significant flooding events, such as the Halloween 2021, July and December 2023, and July 2024 floods. It is anticipated that the pilot channel will continue to adjust in 2025, as natural river channel evolution processes are restored. In Year 1, incision was the primary factor contributing to adjustment observed at the project site. In Year 2 and 3, continued bank failure along with the formation of lateral channel bars, indicate that this reach of the Bogue Branch is continuing to widen and beginning to form floodplain features. As mentioned in the Year 2 (2023) monitoring report, the installed rootwads at both locations (WR1 and WR2) were no longer functioning as intended. Although the original rootwad installations are not recruiting new woody debris, other points along the channel and newly formed bars are, an increase in newly tagged woody debris was seen in 2024.

Based on the aerial imagery and monitoring data summarized in this report, the Bogue Branch and stream habitat features in the monitoring reach are also continuing to adjust. Woody debris and the formation of pools are providing habitat for aquatic organisms in the former impoundment. The final project report in Year 4 will include additional analysis of DEM and vegetation health data collected by UAV. Overall, initial comparisons of streambed elevations show signs of deposition downstream of the former dam location, indicating that the restoration of natural sediment transport processes may be providing a source of sediment for a previously sediment starved reach of Bogue Branch. Additionally, this analysis will allow us to quantify the volume of sediment eroded along the outside of meander bends.

Attachment 1: Orthoimagery

Orthoimagery from March 25, 2024

Orthoimagery from July 29, 2024

Orthoimagery from October 25, 2024

N

0 250 500 Feet